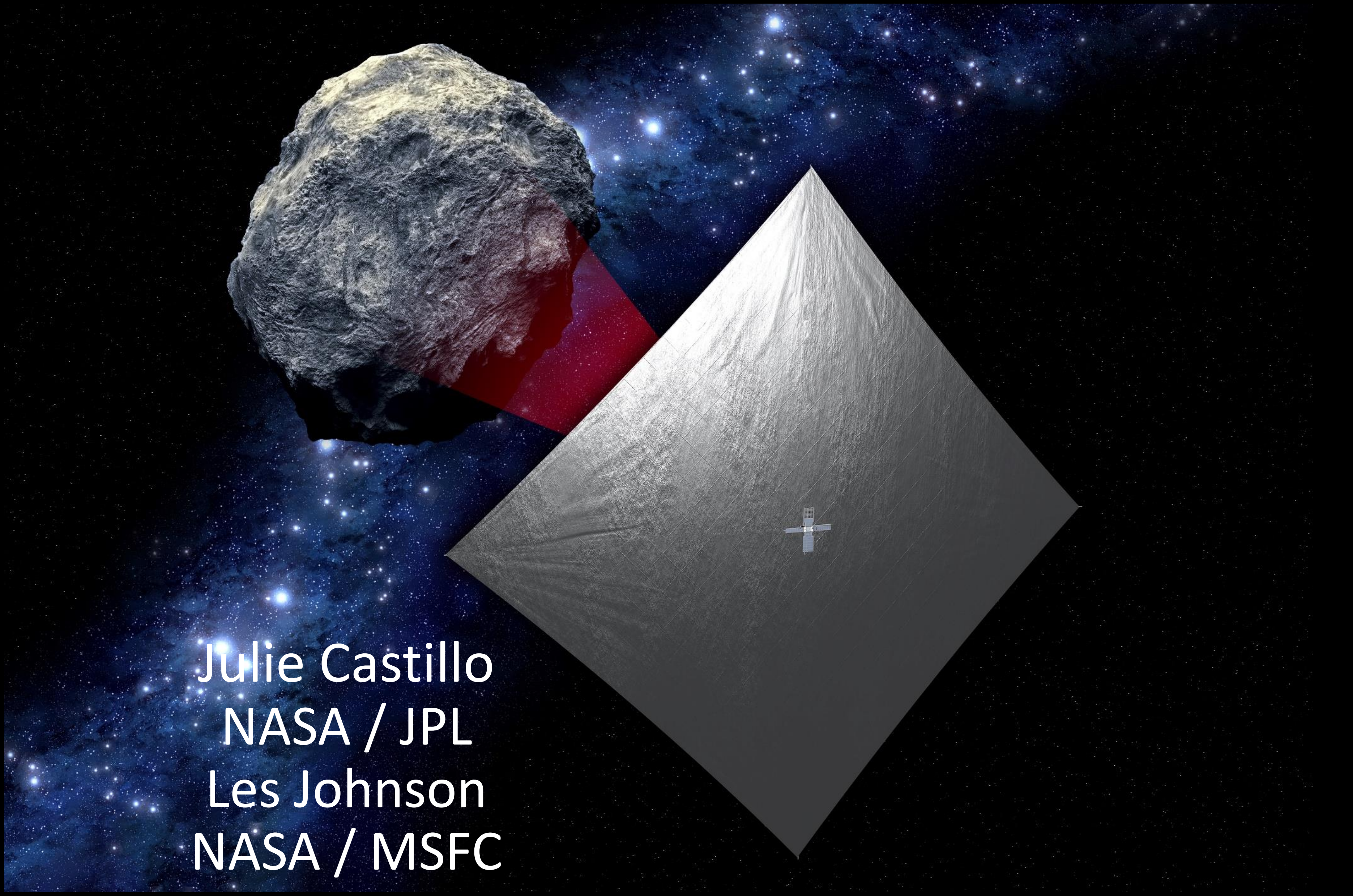
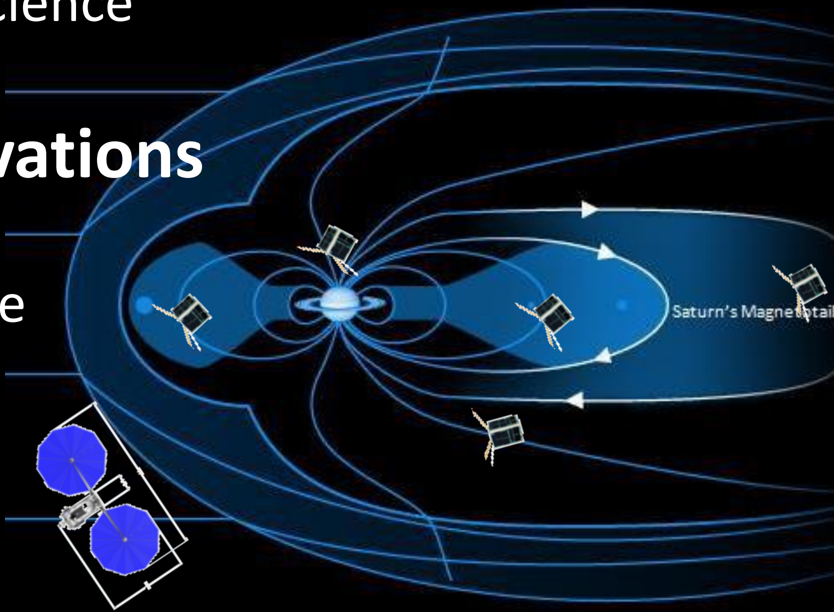
Near Earth Asteroid Scout (NEA Scout): The USA's First Solar Sail Propelled Interplanetary Science CubeSat



Julie Castillo
NASA / JPL
Les Johnson
NASA / MSFC

Science Pull for SmallSats

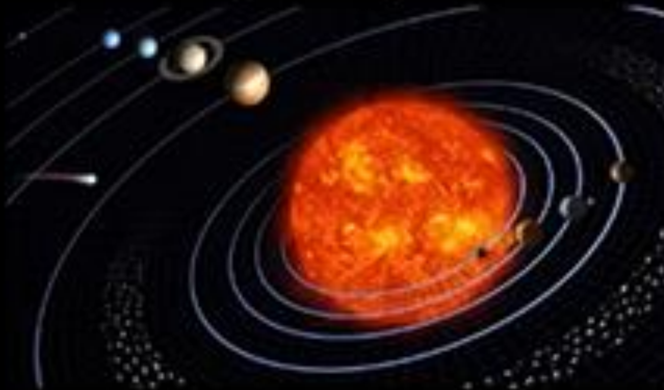
- **New science enablers**
  - Distributed measurements for dynamic processes
  - Impactor/observer architecture (cooperating assets)
- **Alternative low-cost architectures**
  - Fractionated payload for system science
- **High-risk, high-reward observations**
  - Access to unique vantage points
  - Risk assessment by sacrificial probe
- **Rapid Response**
  - Comets, NEOs (Planetary Defense)



WHY EXPLORING NEAR EARTH ASTEROIDS?

SCIENCE

Revealing Solar System History



DEFENSE

Mitigating Impact Hazards

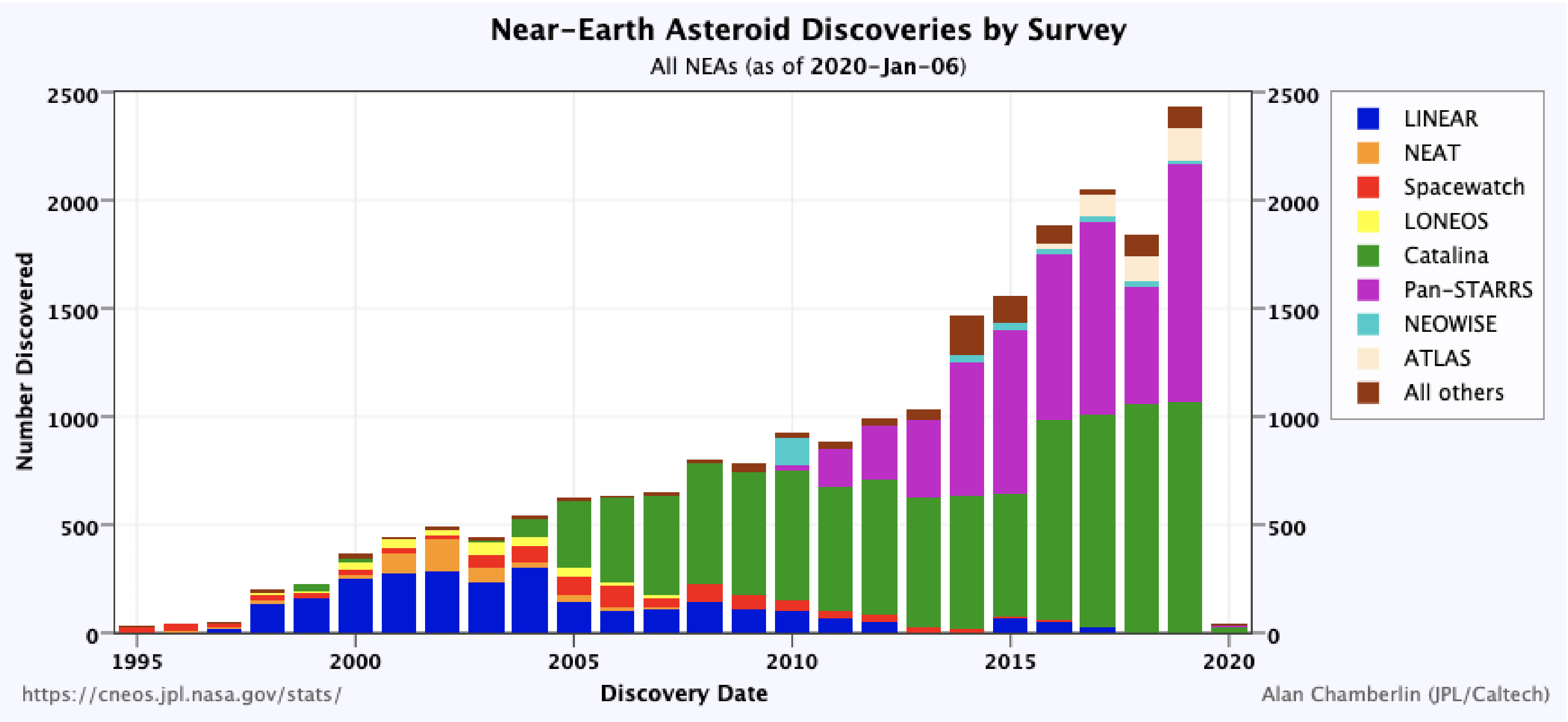
EXPLORATION

Enabling Human Exploration

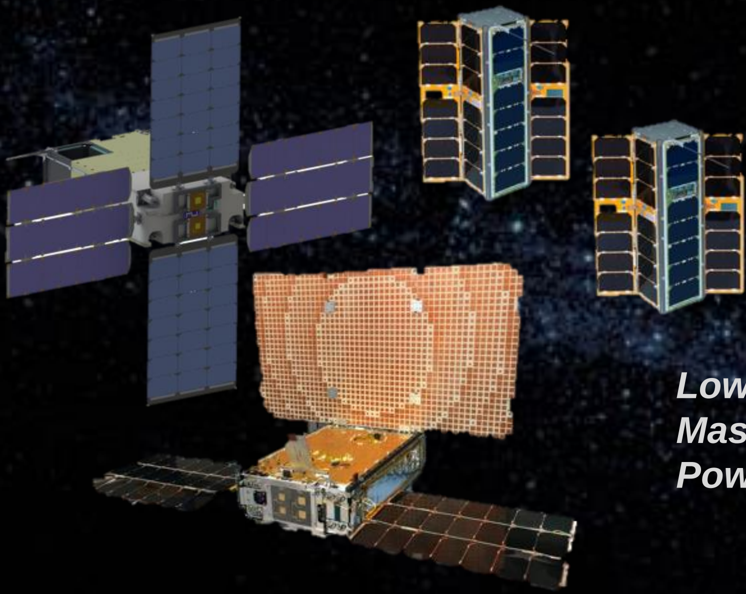
RESOURCES

Developing a Space Economy

NEA Discoveries Have Been Exploding Over The Past Decade



TODAY



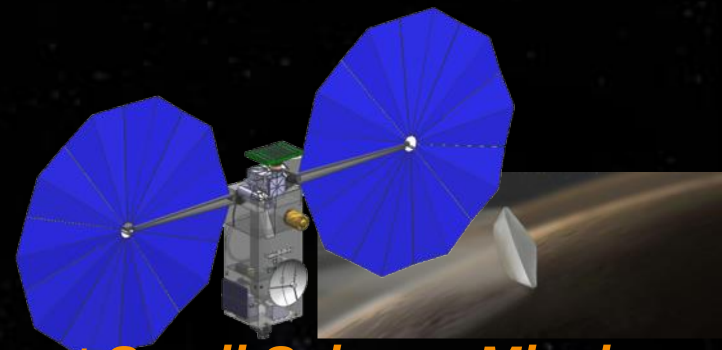
Lower Mass & Power

Technology Demonstrations

Instruments and spacecraft components

Near Earth Asteroid Scout (NEA Scout): The USA's First Solar Sail Propelled Interplanetary Science CubeSat

FUTURE



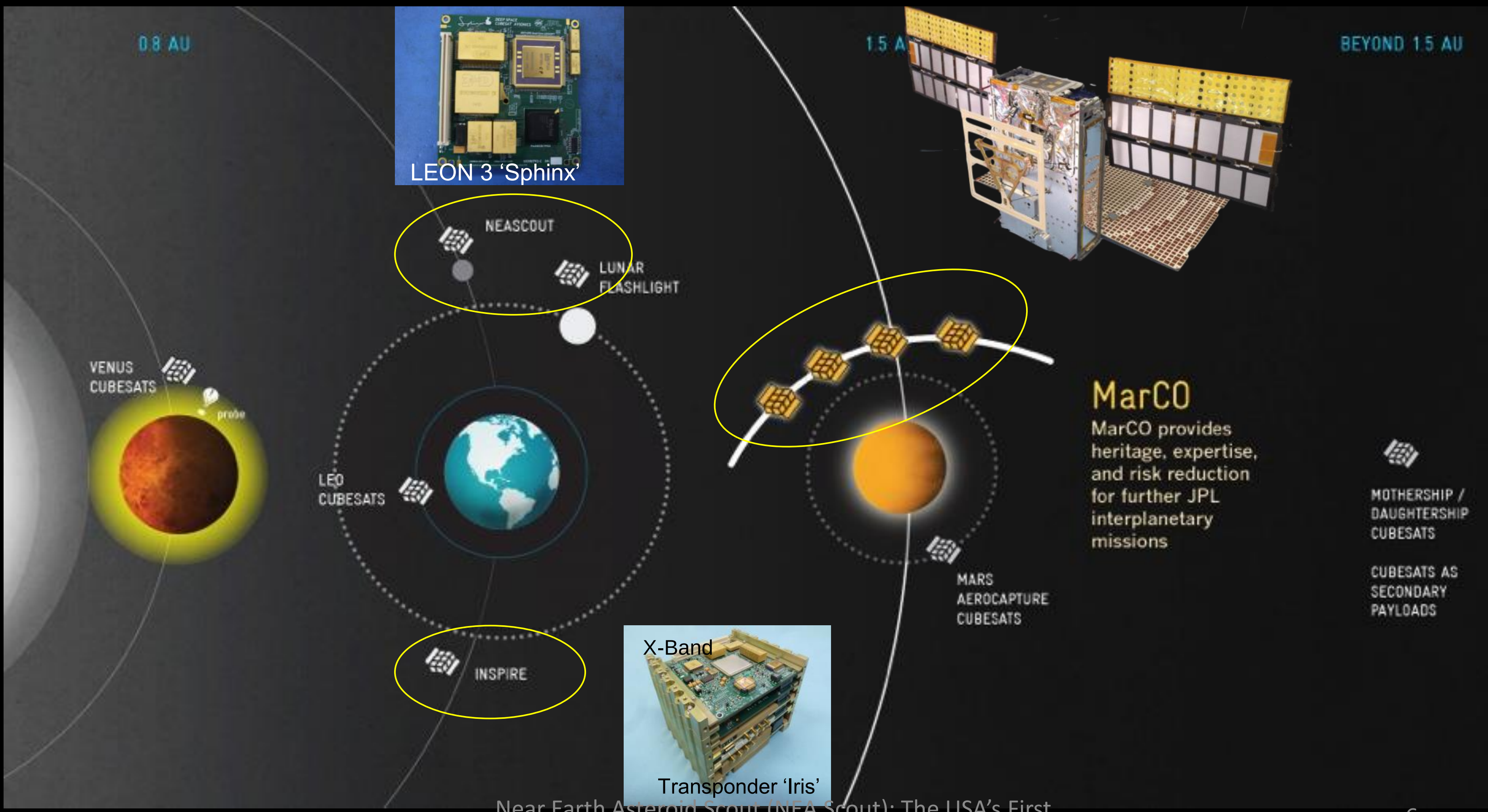
Lower cost Small Science Missions

Inner solar system (≈$100M)

More Affordable Outer Planet Missions

Future Ocean World Probes

INSPIRE, MarCO, and EM-1 CubeSats as Stepping Stones to Deep Space



Jet Propulsion Laboratory
California Institute of Technology

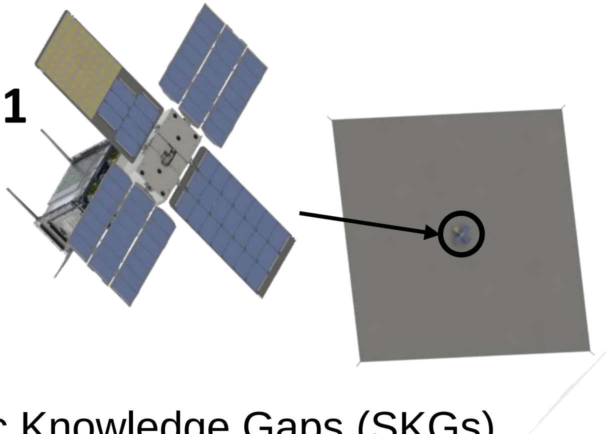
Marshall Space Flight Center

Science Principal Investigator: Julie Castillo-Rogez (JPL/Caltech)
Solar Sail Principal Investigator: Les Johnson (MSFC)
Project Manager: James Stott (MSFC);Deputy Project Manager: Calina Seybold (JPL/Caltech)
PSE: Matthew Pruitt (MSFC)

Sponsored by NASA HEOMD/Advanced Explorations Systems
https://www.nasa.gov/content/nea-scout

THANK YOU NEA SCOUT TEAM!!!

Near Earth Asteroid (NEA) Scout



1 of 13 CubeSats to launch with Artemis-1 in the Fall 2021

- Selected in 2013, MCR in 2014, Design Review in 2016
- Fully integrated and tested, delivered in July

GOALS – Science and Technology Demonstration

- Characterize a NEA with an imager to address key Strategic Knowledge Gaps (SKGs)
- Demonstrates low cost reconnaissance capability for HEOMD (6U CubeSat)

LEVERAGES:

- Solar sail development expertise (NanoSail-D, Solar Sail Demonstration Project, LightSail-A/B)
- CubeSat developments and standards (MarCO, University & Industry experience)
- Commonalities with other AES secondary payloads (e.g., Lunar Flashlight)

Key Technical Constraints:

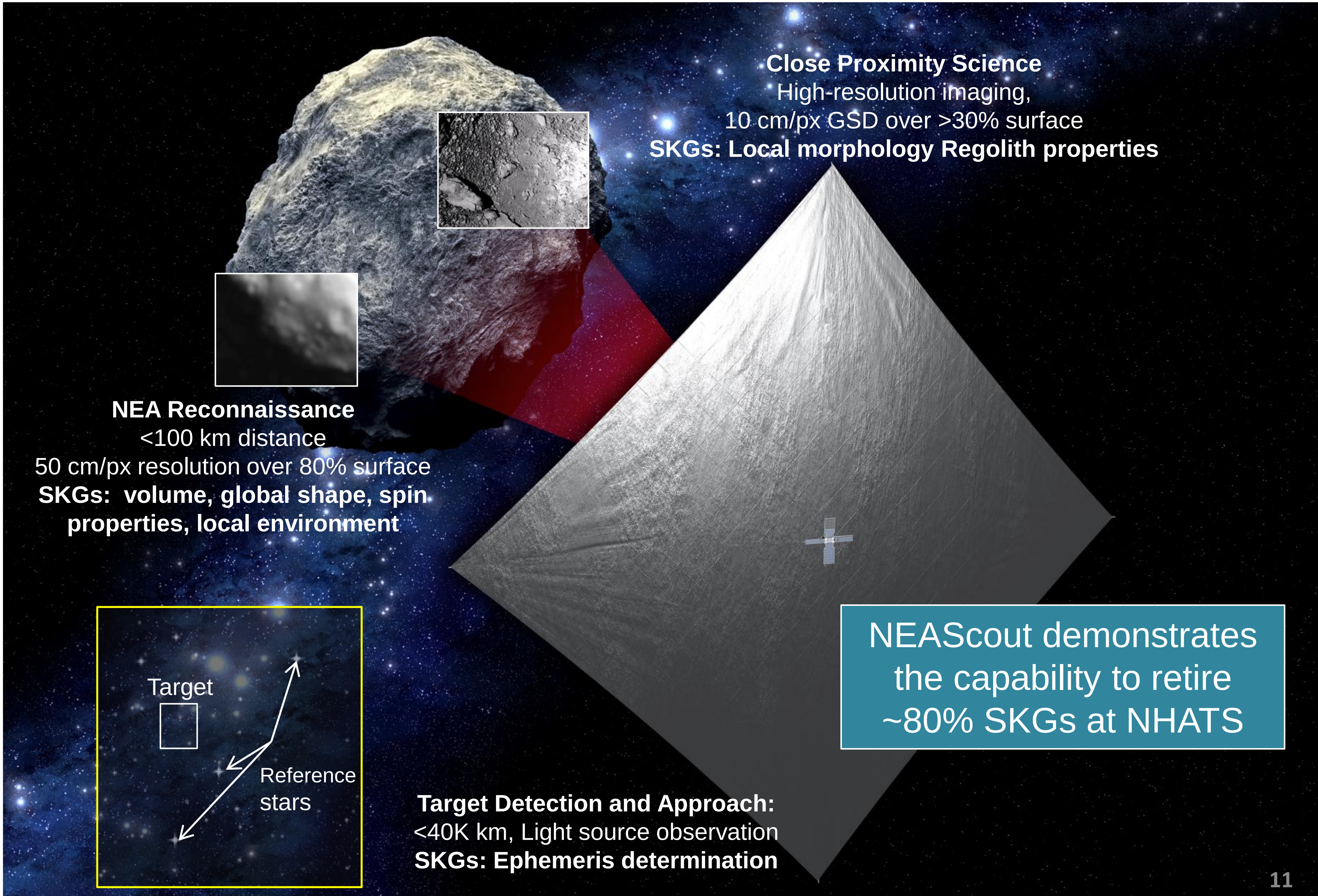
- 6U Cubesat and ~86 m^2 sail
- COTS drive mission duration <2.5 yr
- Target must be within ~1.0 AU distance from Earth due to telecom limitations
- Slow flyby (5-20 m/s) with target-relative navigation on close approach

STRATEGIC KNOWLEDGE GAPS FOR HUMAN EXPLORATION

HEO-Defined Strategic Knowledge Gaps	Expected Performance	Risk Reduction or Benefit
Location (position prediction/orbit)	OCC decrease to 0	🔵 🔴 🟡
Size (existence of binary/ternary)	High accuracy on size, detection of satellites	🔵 🔴 🟡 🟢
Rotation rate & pole orientation	High accuracy on pole and velocity	🔵 🔴 🟡 🟢
Particulate environment/Debris field	**Characterization of particle density in target vicinity**	🔵 🔴 🟡 🟢 ⚫
Regolith mechanical & geotechnical properties	***Indirect*** *(imagery interpretation)*	🔵 🔴 🟡 🟢 ⚫
Mass/density estimates (internal structure)	***Indirect*** *(based on taxonomic characterization)*	🔴 🟡 🟢
Surface morphologies and properties	**Morphology at resolution of astronaut's foot**	🔵 🔴 🟡 🟢 ⚫
Mineralogical & chemical composition	***Indirect*** *from taxonomic characterization*	🔵 🔴 🟡 🟢 ⚫

🔵 Crew/Mission 🔴 Operations 🟡 Cost 🟢 Performance ⚫ Science/Engineering

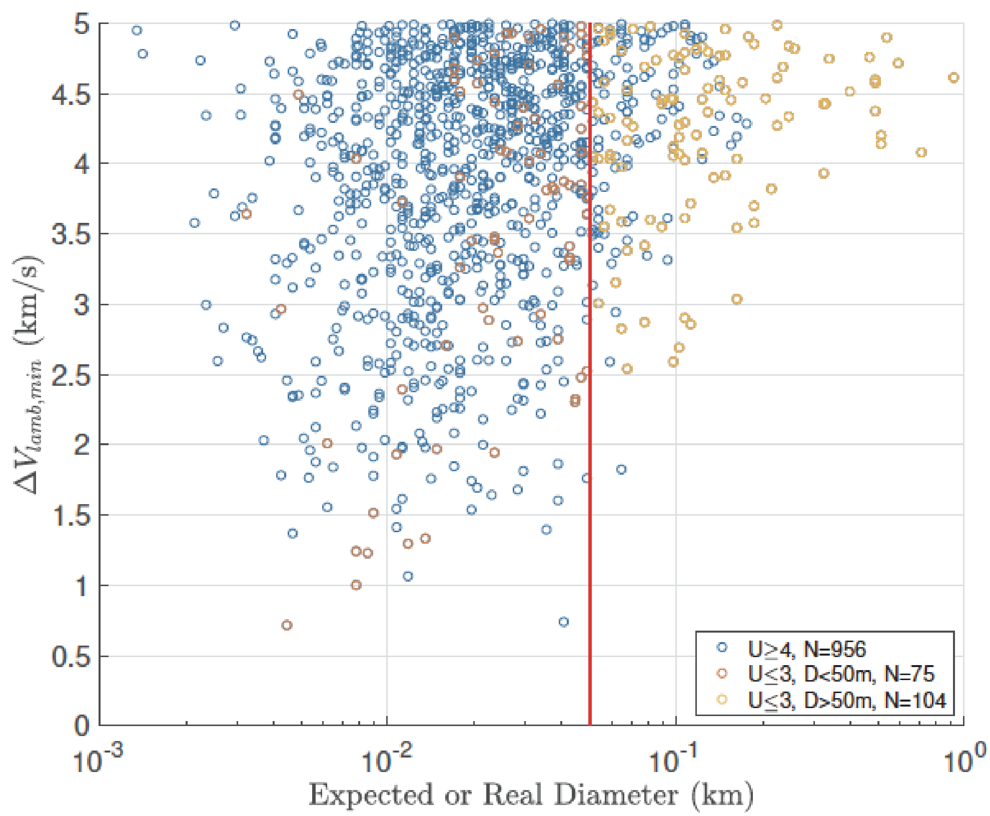
Science Measurements



NEA Scout Targets NHATS

- NHATS database contains ~4000 targets from 1 m to >1 km
- Targets accessible to NEAScout are < 50m
- **About one target available for any launch window**
- Coordination with NEO Program Office at JPL (CNEOS) and astronomy community
- About 1 new accessible NEAs found each year
- NEAScout has the capability to reach challenging targets (H~28-29, OCC~1-2, telecom distance ~1 AU)

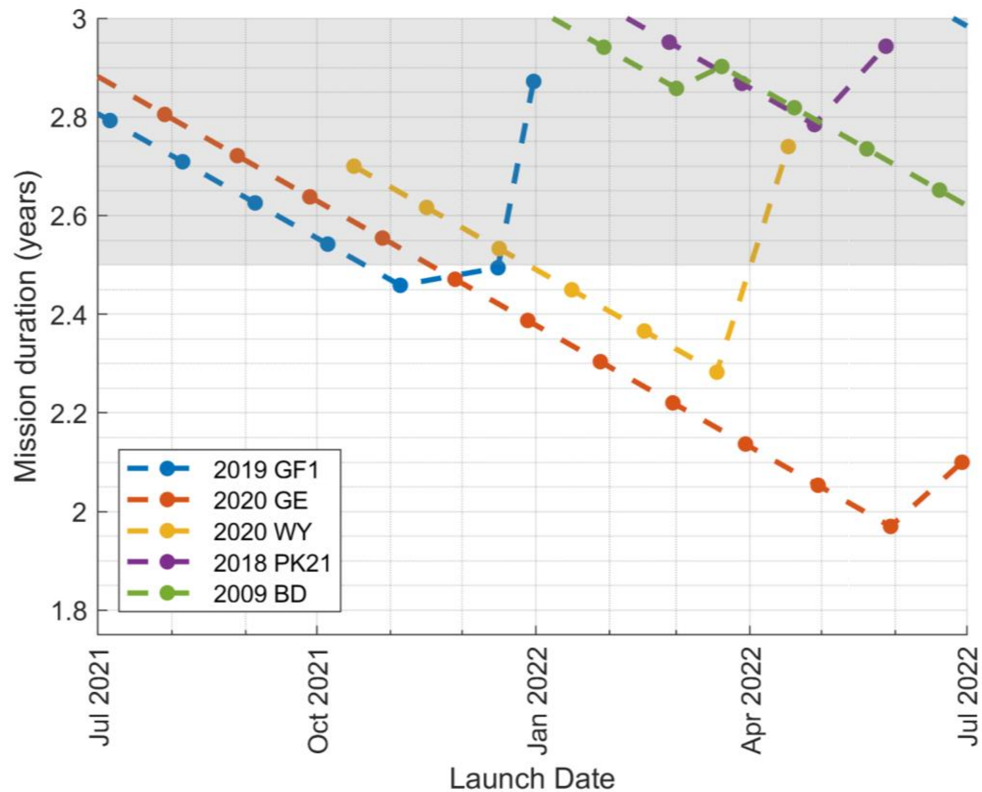
NHATS = Near-Earth Object *Human* Space Flight Accessible Targets Study



Currently accessible targets are well within NEAScout' capability

Baseline Target: 2020 GE

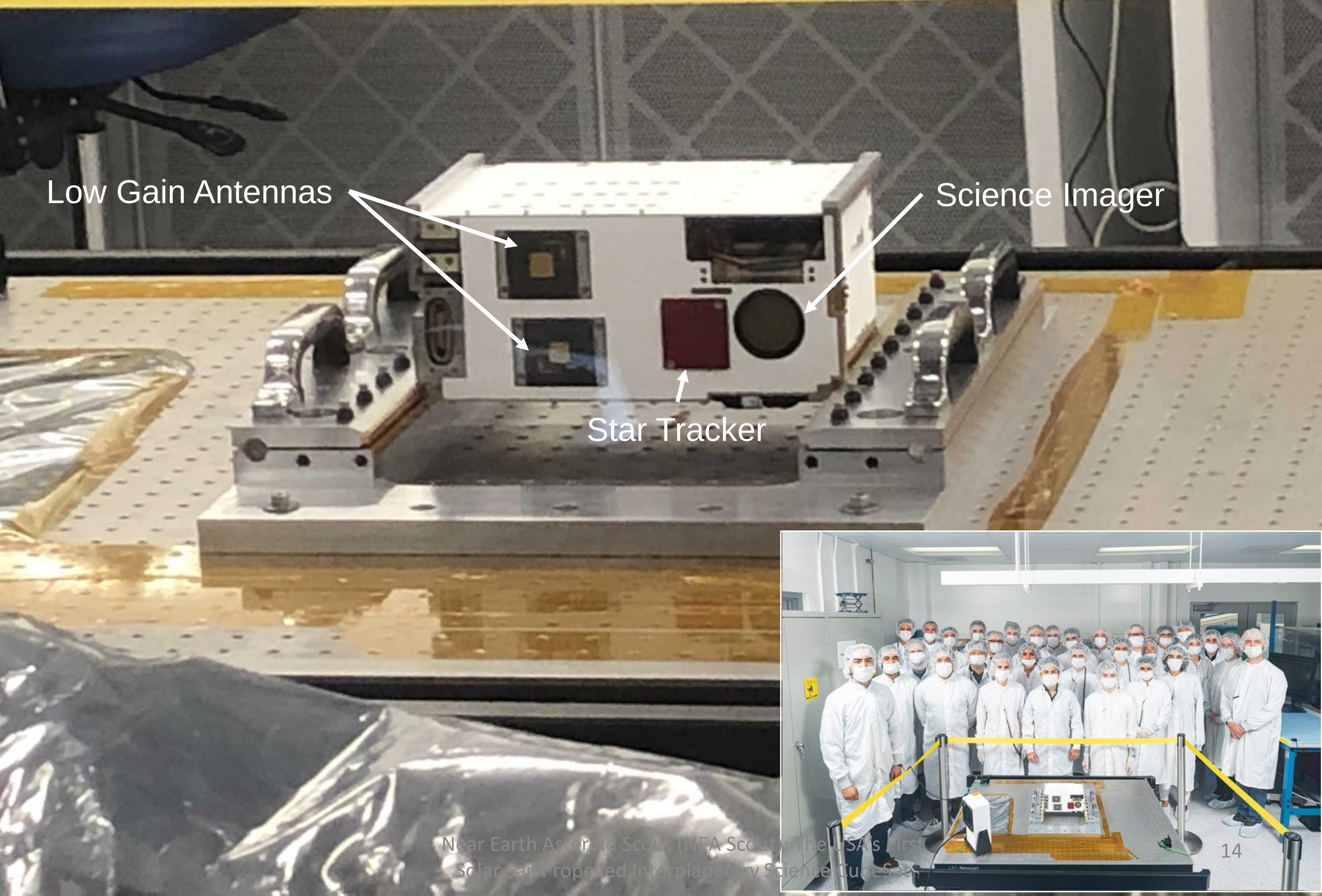
- Earth-crossing asteroid
- Potential “pebble” or lunar ejecta based on dynamical properties
- Magnitude H=28.1 → Diameter ~ 4-18 m (unknown albedo)
- Encounter in 11/2023, shortly after 2020 GE’s close Earth flyby
- Position is known within ~100s km
- **Telecom distance is ~0.15 AU at closest approach**
- Rotation period is unknown
- Unlikely to have a companion and retain a dust cloud



Data points assume:
Optimal lunar escape (not designed yet)
Medium-fidelity cruise (w/ 1-month margin)
1-month approach
6-month downlink

Baseline target is appealing for SKGs, Science, and Planetary Defense

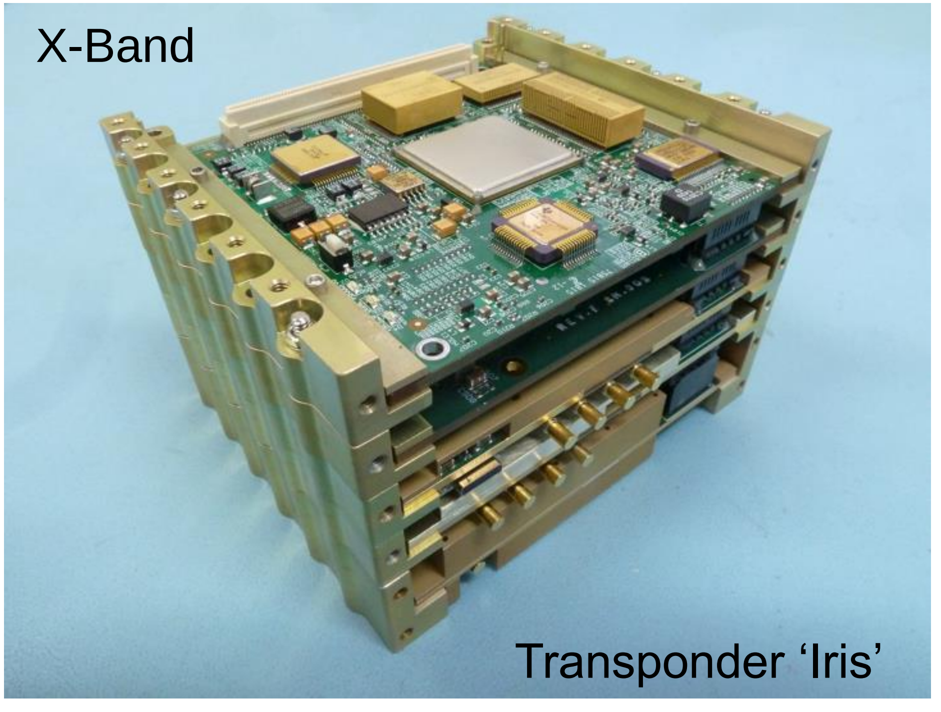
Delivery of Avionics Box to MSFC in May 2019



Current Capabilities and Investments

to address deep space challenges

Communication and Navigation

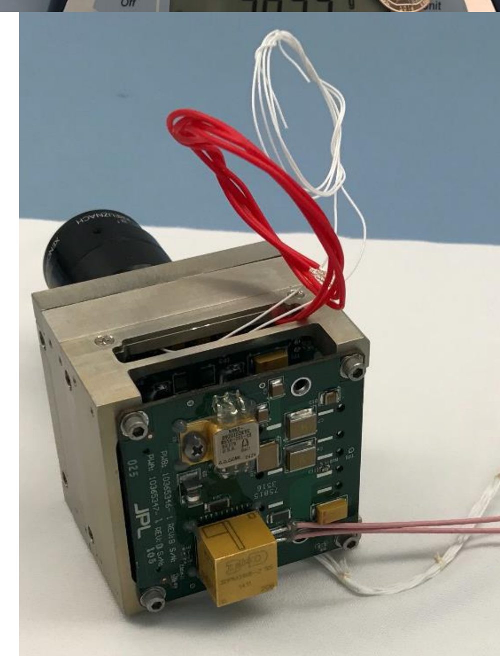


http://www.jpl.nasa.gov/cubesat/missions/iris.php

Radiation Hardened

NEA Scout Flies the Smallest Science-Grade, Deep-Space Camera

- ~400 gm, $^1/_2$ U, <3W, standard interfaces
- FOV ~27 deg., iFOV~0.127 mrad
- 20 MPx EECAM detector (16 MPx usable)
- **Fully calibrated**
- Limitations: local storage of ~2 images; data transfer rate via SpaceWire is ~4.5 MPx/sec
- Flight spare on ATB
- Absolute photometric performance <1%
- Achieves 10 cm/pix from 800 m
- Doubles as Navigation camera
  - Detects H-28 target in a few 100s ms from >40K km



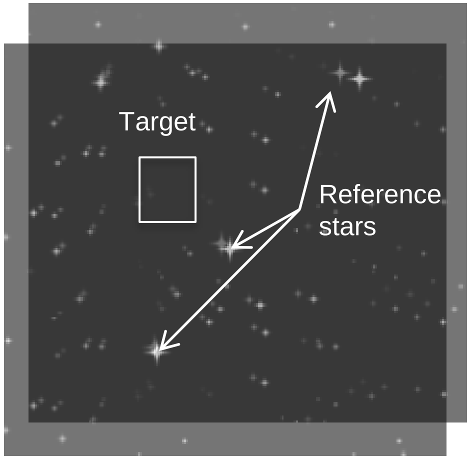
NEACam Meets or exceeds Science and NAV requirements

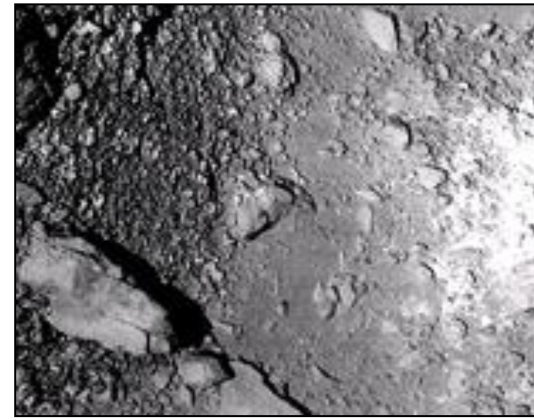
Test Image in the Lab, Before and After Calibration

Note: focal distance >10m could not be met during testing

NEA Scout Carries On-Board Image Processing

ACTIVITIES





Target Detection and approach with wide field imaging
Ephemeris determination

Target Reconnaissance with medium field imaging
Shape, spin, and local environment

Close Proximity Imaging
Local scale morphology, terrain properties, landing site survey

CHALLENGES

Limited downlink (<4kbps)
Large target position uncertainty

Limited downlink (<1-4kbps)
Short flyby time (<60 min.)
Uncertain environment

Limited downlink (<1-4kbps)
Short time at closest approach (<20 sec.)

APPROACH

Capture position ellipse in one FOV
Image co-adding
subwindowing
Lossless Compression

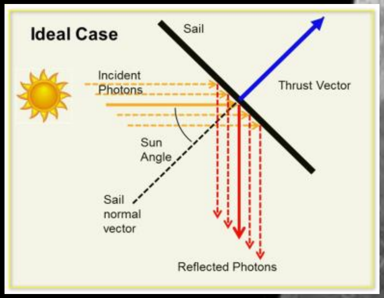
Thumbnails, triage, lossless compression, subwindowing
Autonomous target pointing (center of brightness)

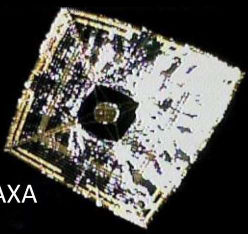
NEAS' approach to on-board data processing is a pathfinder for future autonomous missions

NEA Scout: Sailing On Sunlight

- Producing thrust with sunlight "pressure" or force on thin, lightweight, reflective sheets

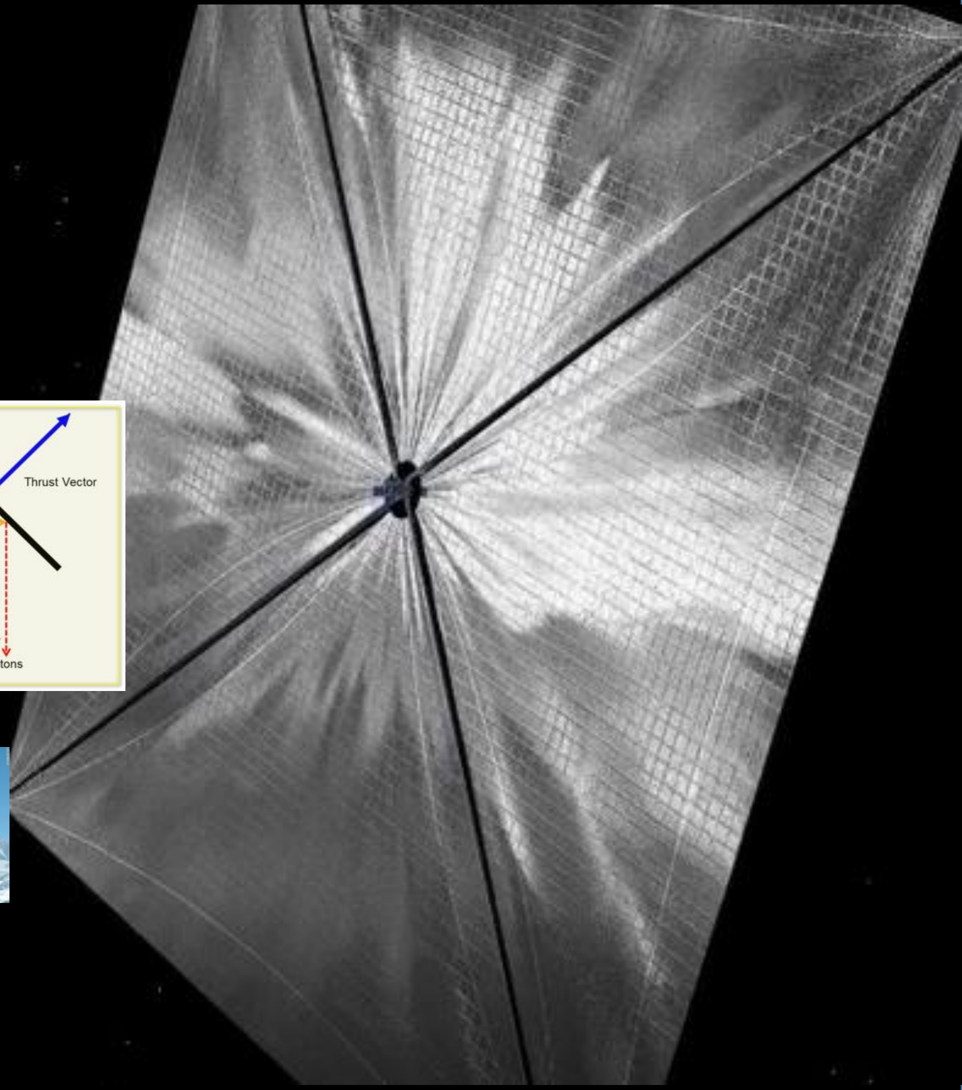
- Allows space missions to new, propulsion-intensive locations



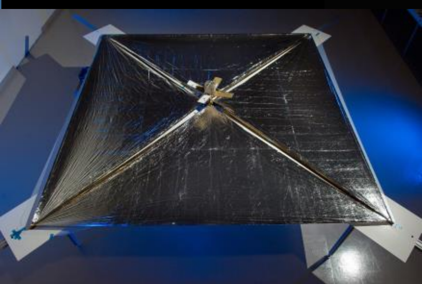


JAXA

The Planetary Society



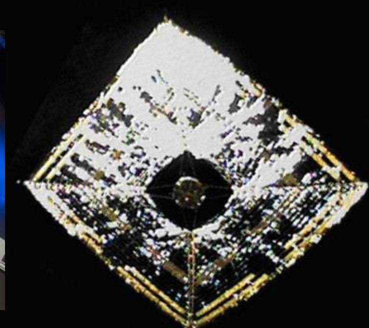
Solar Sail Missions Flown



NanoSail-D (2010)
NASA

Earth Orbit
Deployment Only

3U CubeSat
10 m^2



IKAROS (2010)
JAXA

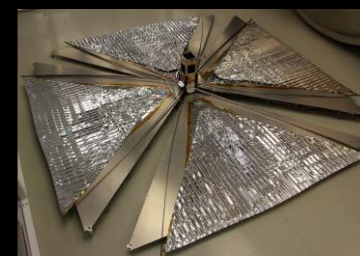
Interplanetary
Full Flight

315 kg Smallsat
196 m^2

LightSail-1 & 2
(2015/2019)
The Planetary Society

Earth Orbit
Deployment / Flight

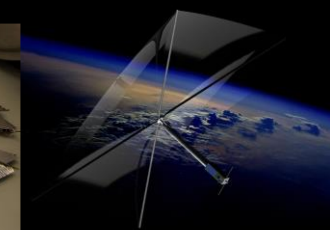
3U CubeSat
32 m^2



CanX-7 (2016)
Canada

Earth Orbit
Deployment Only

3U CubeSat
<10 m^2

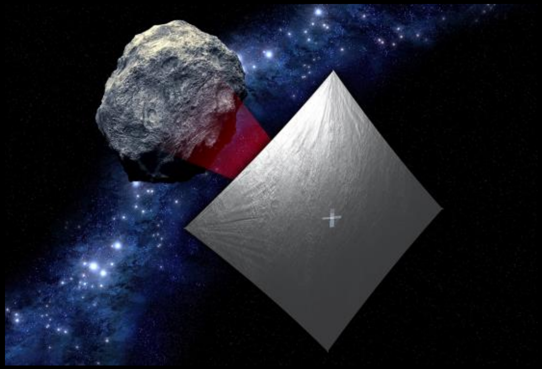


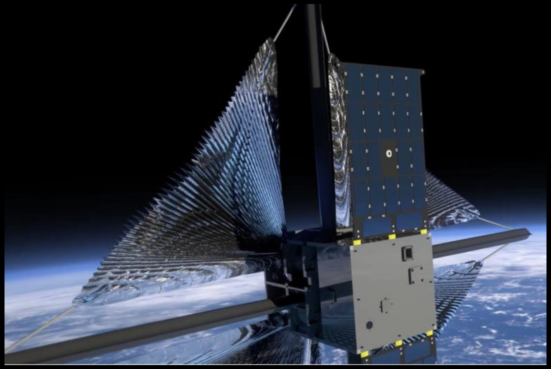
InflateSail (2017)
EU/Univ. of Surrey

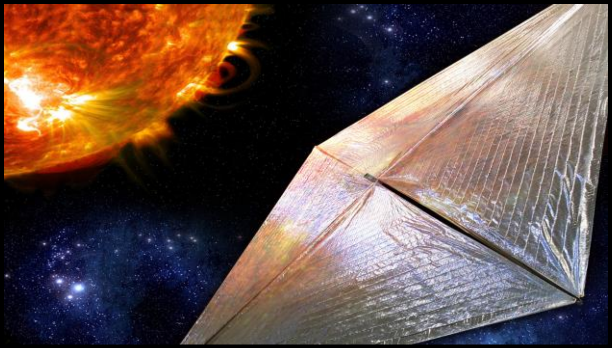
Earth Orbit
Deployment Only

3U CubeSat
10 m^2

Planned Solar Sail Missions







Near Earth Asteroid Scout (2021) NASA

Interplanetary
Full Flight

6U CubeSat
86 m^2

Advanced Composite Solar Sail System (2022) NASA

Earth Orbit
Full Flight

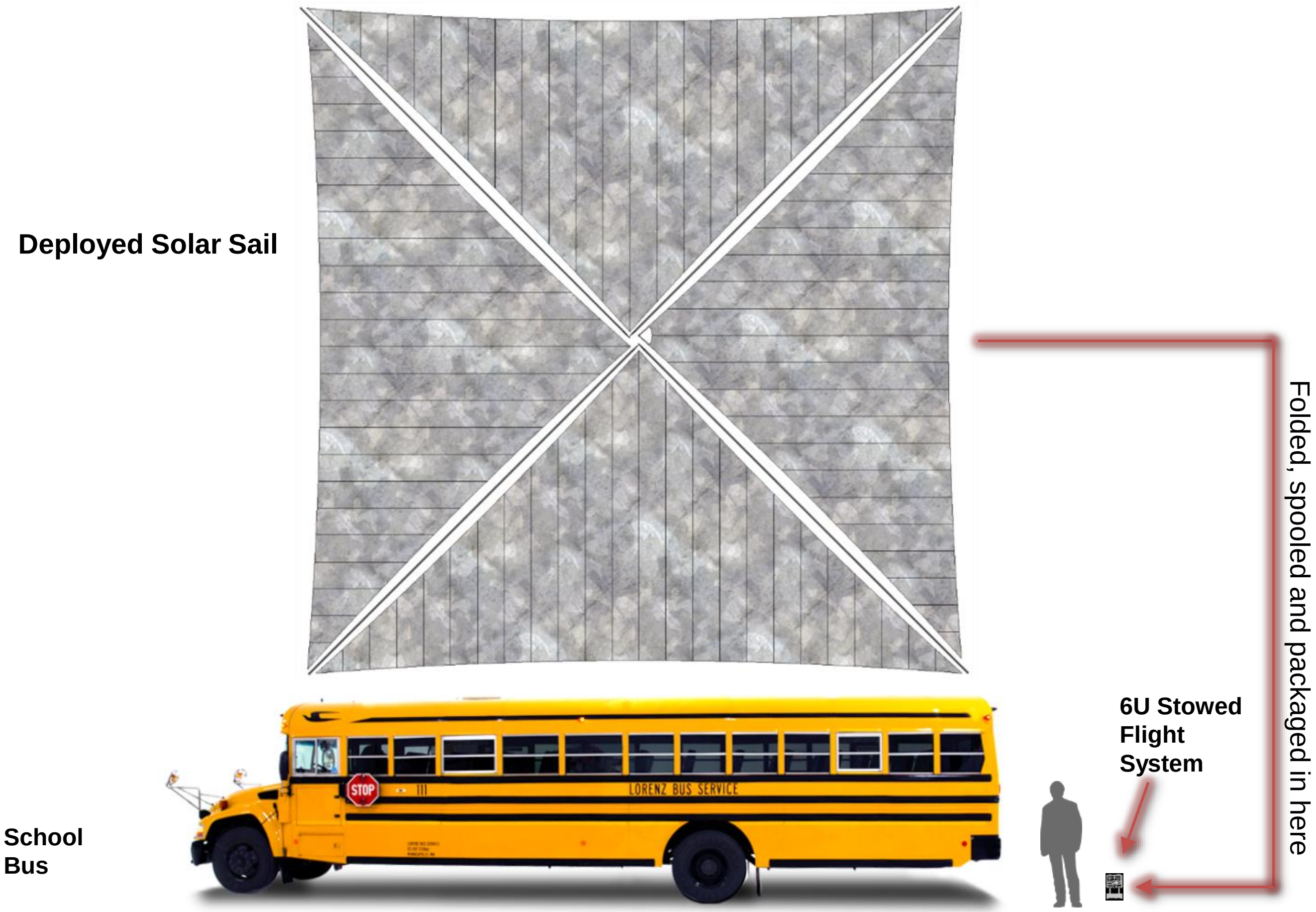
12U CubeSat
74 m^2

Solar Cruiser (2025) NASA

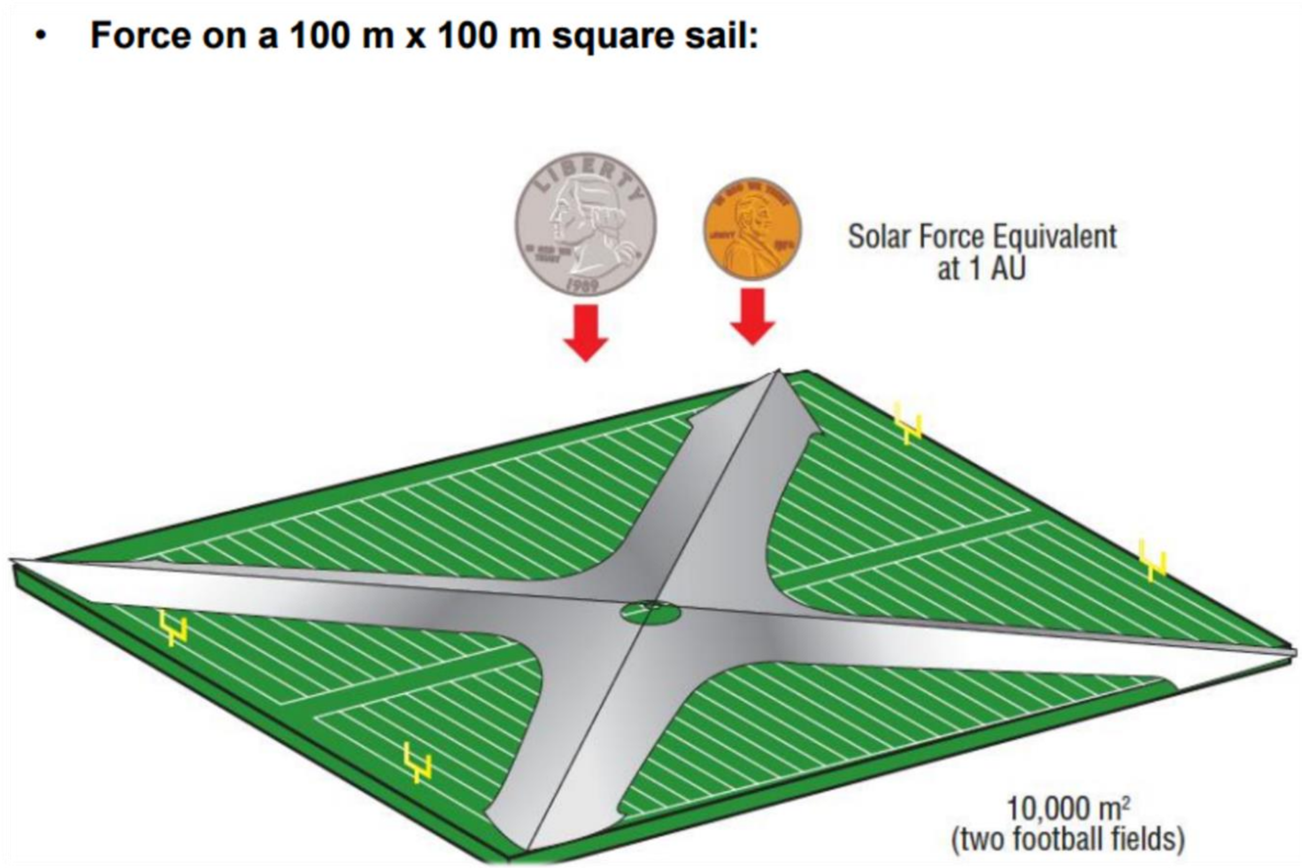
Interplanetary
Full Flight

100 kg spacecraft
1653 m^2

NEA Scout Approximate Scale



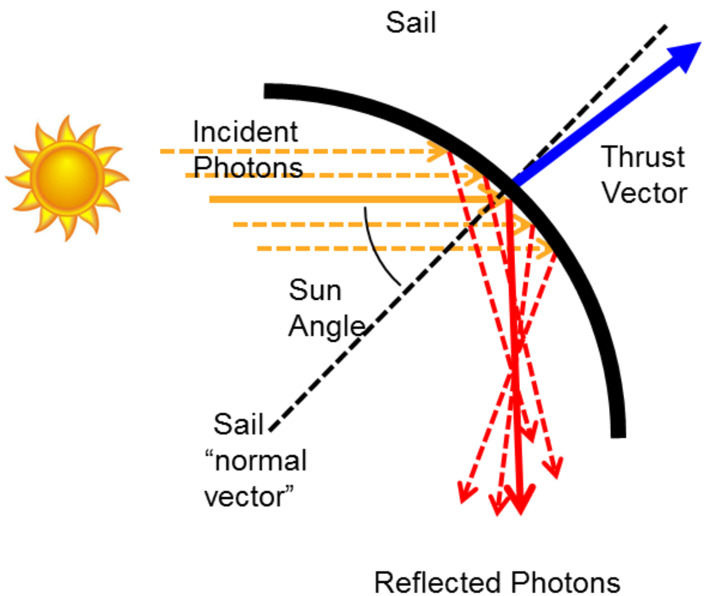
Solar Sails Experience VERY Small Forces and Reduce or Eliminate the Need for Propellant

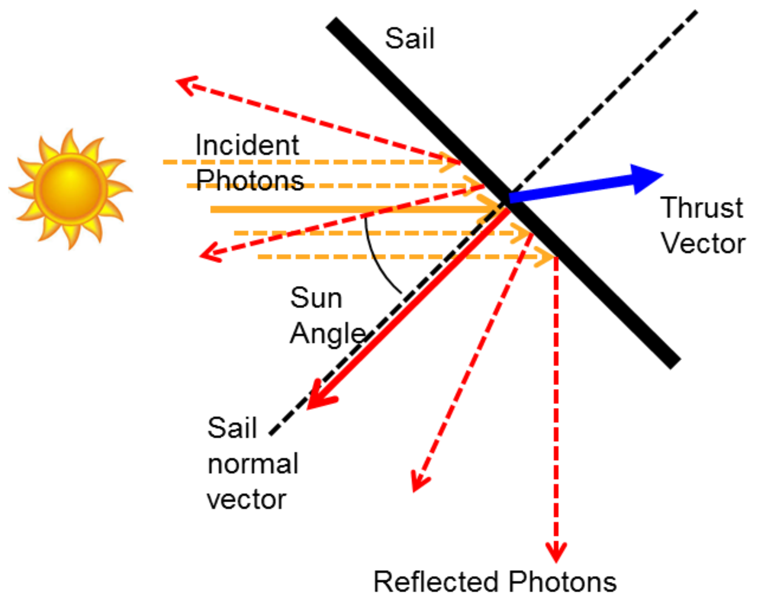


In 2.5 years of flight, NEA Scout will generate:

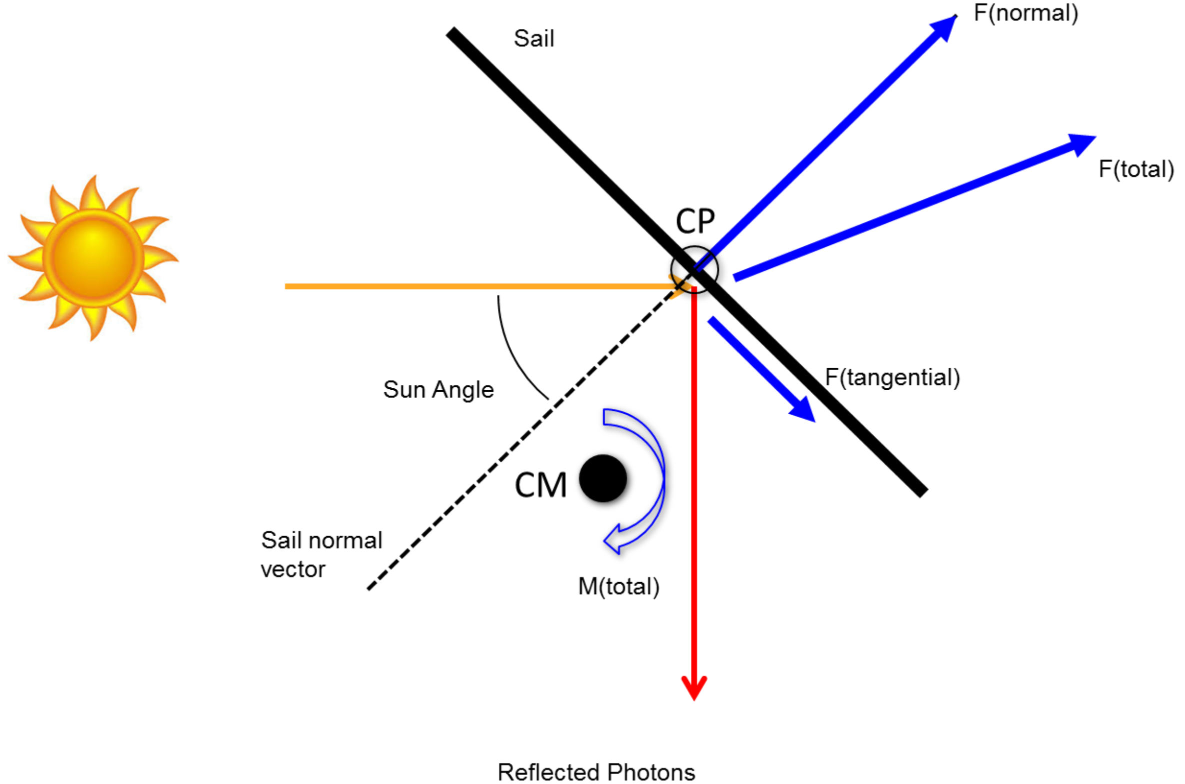
$\Delta V = 3 – 5$ km/sec

Real Solar Sails Are Not "Ideal"



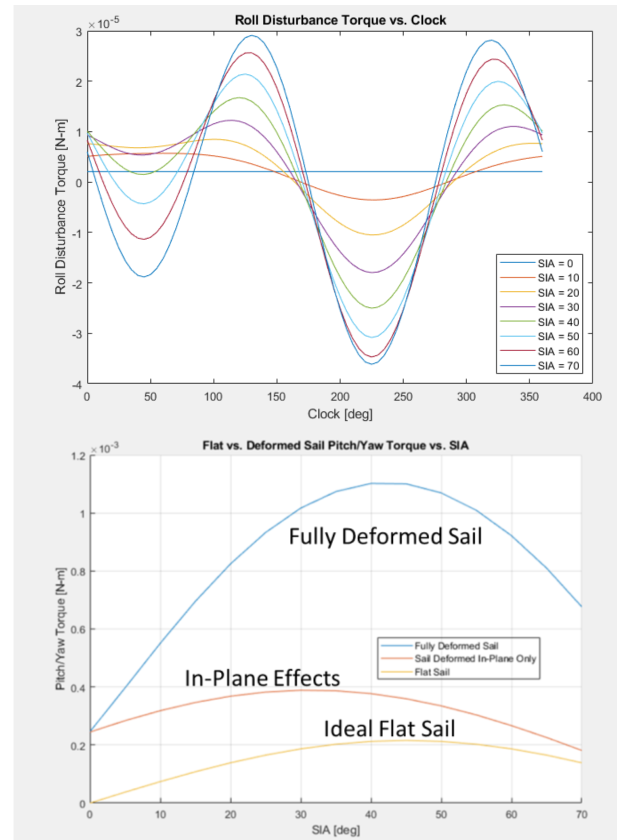


Thrust Vector Components and Momentum Management



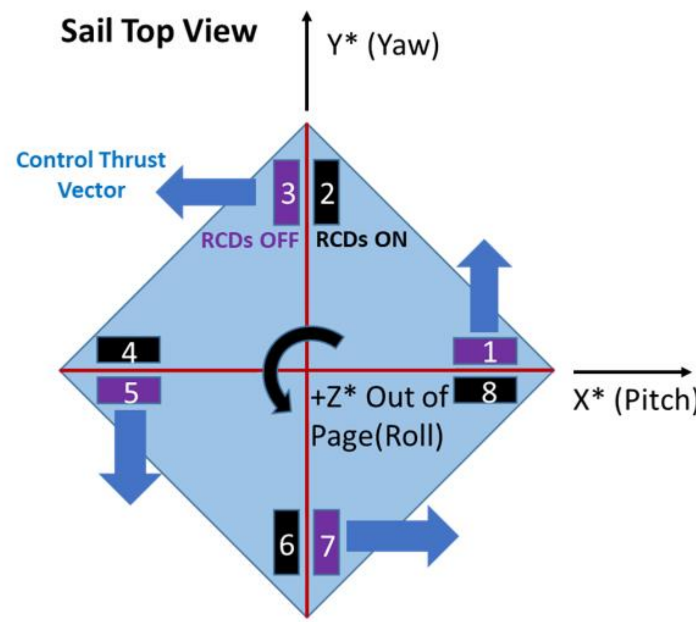
Attitude Control and Momentum Management Challenges

- Architecture must consider:
  - Highly-dynamic disturbances (e.g., flex dynamics) for finer pointing control.
  - Less dynamic solar disturbances.
  - Sun Incidence Angles and slew rates required for the mission and any clock angle constraints.
- Sail/boom deformations and CM/CP offsets must be considered to properly estimate solar disturbance torques for actuator sizing.
- Increasing sail area causes:
  - Greater peak solar disturbance torques.
  - Higher-amplitude and lower-frequency flex modes.
  - More inertia to accelerate for slewing.

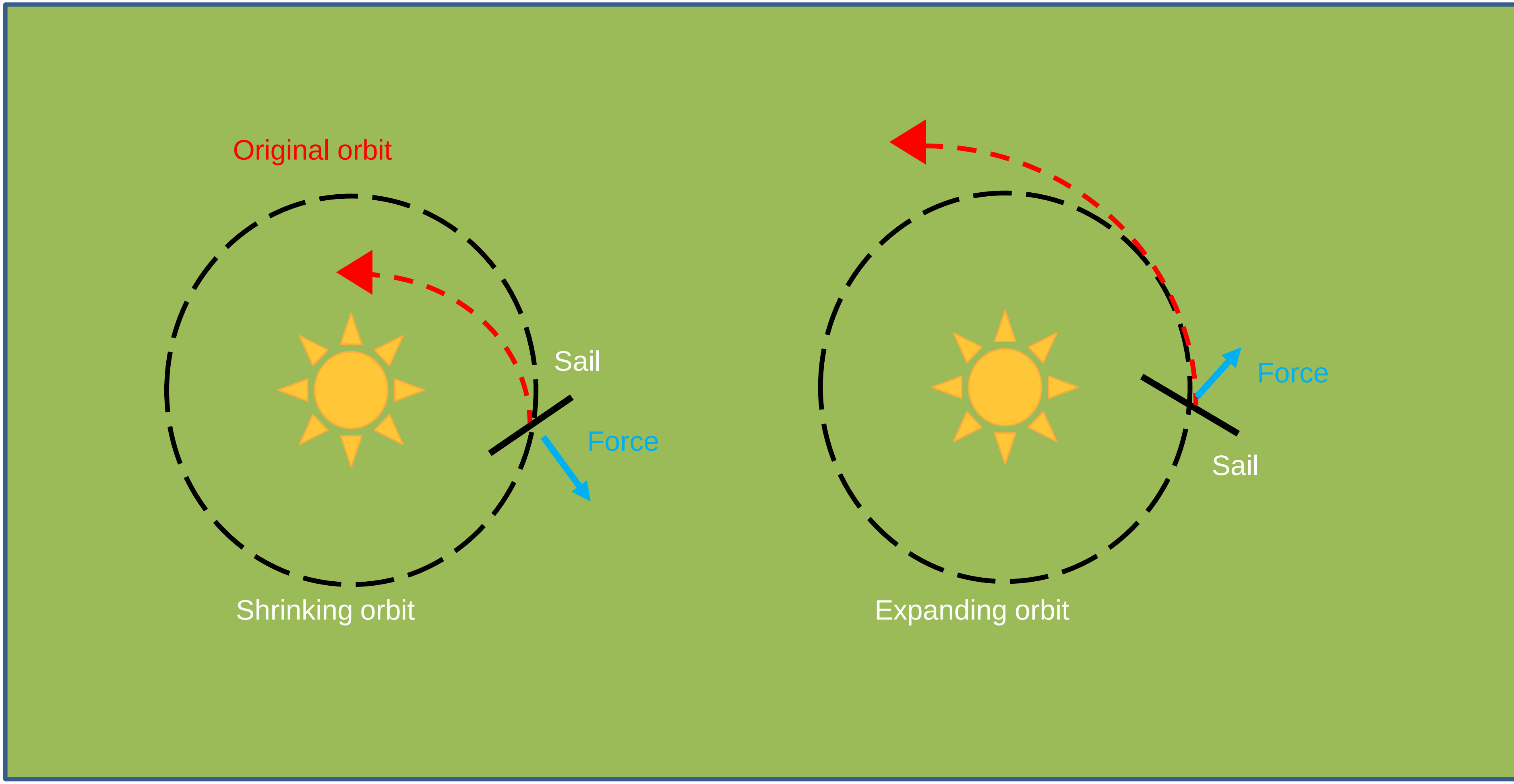


Attitude Control and Momentum Management Architectures

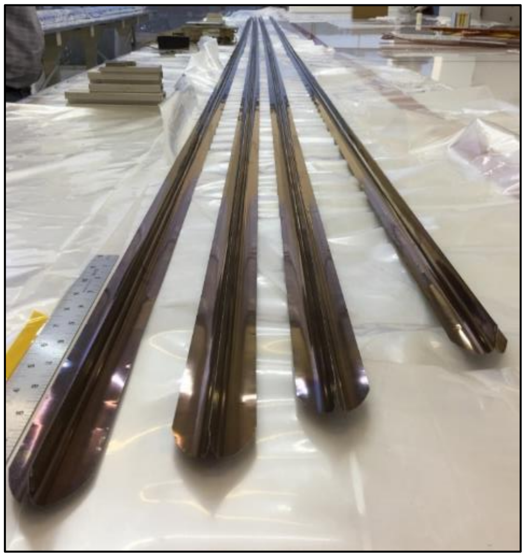
- Stabilization Approaches:
  - 3 axis-stabilized (e.g., NEA Scout & Solar Cruiser) – Better for fine pointing control & slewing.
  - Spin-stabilized (e.g., IKAROS) – Less stringent MM & structural requirements.
- Attitude Control Approaches:
  - Internal momentum exchange devices (i.e., RWs) – More mature and consistent performance at any SIA.
  - External momentum exchange devices (e.g., Reflective Control Devices [RCDs]) – Preclude need for separate MM actuators.
- MM Approaches:
  - CM augmentation (e.g., AMT) – Ideal for large bus-to-sail mass ratios and trimming disturbance torques.
  - Applied torque (e.g., cold gas, RCDs)



Solar Sail Trajectory Control



NEA Scout Flight Sail Deployment Tested



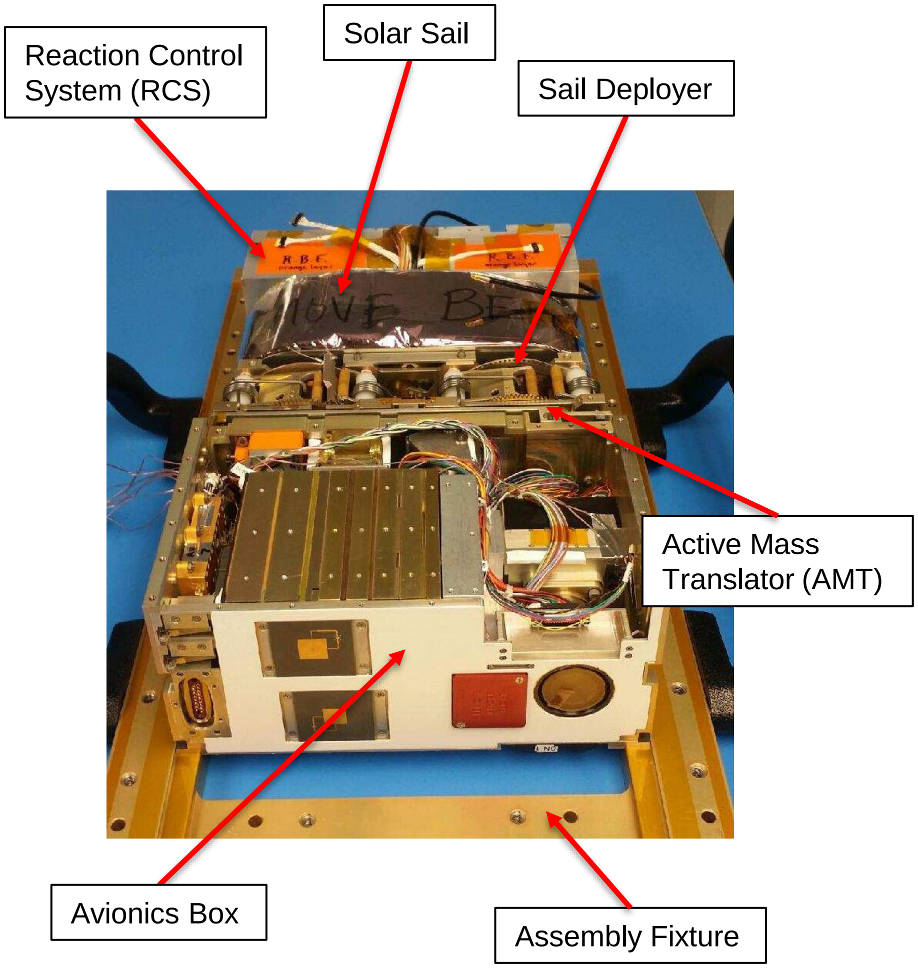
7.3 m booms

Solar Sail Deployment Testing

(Credit: National Geographic)

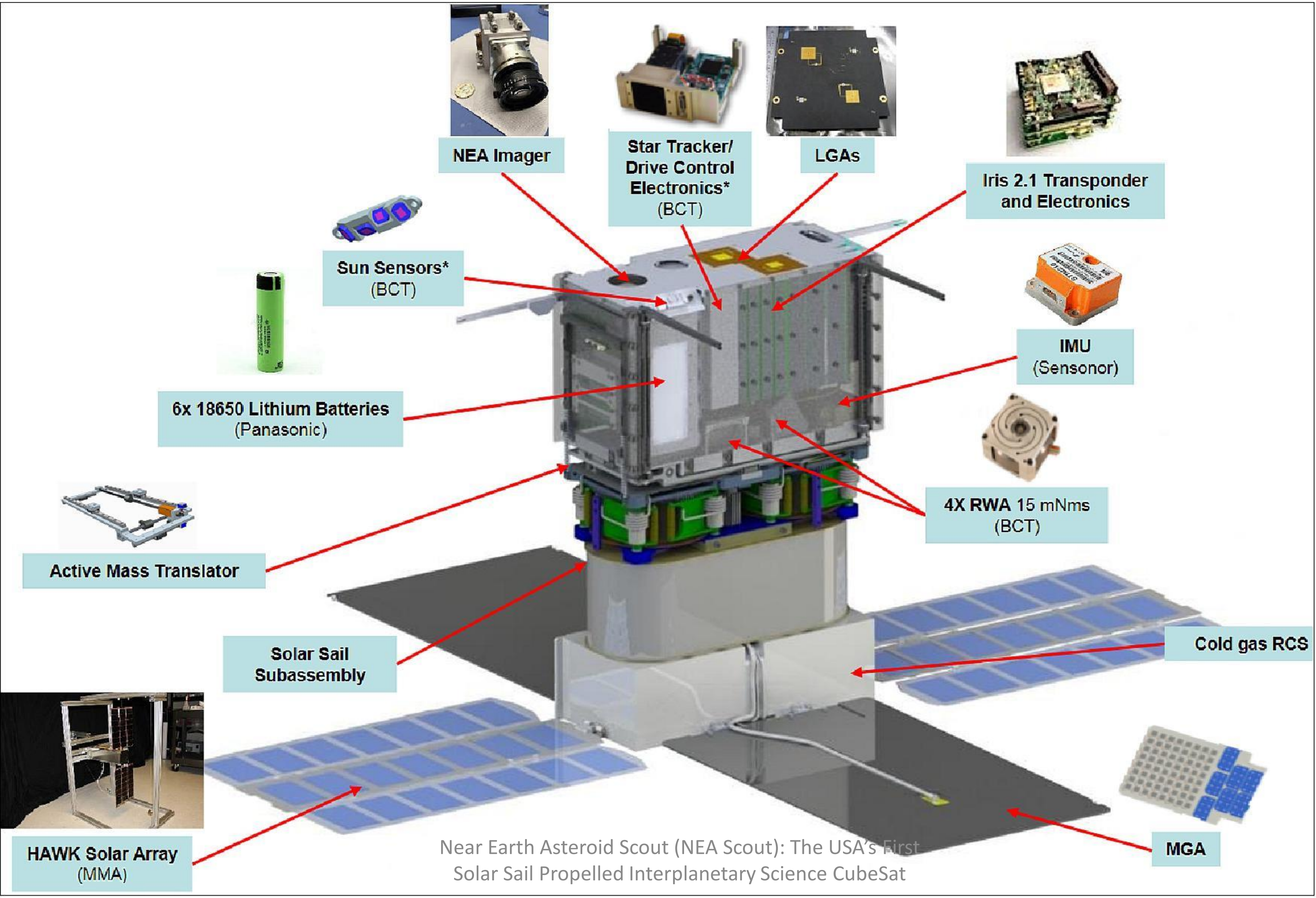
Folded Sail and Integrated Spacecraft

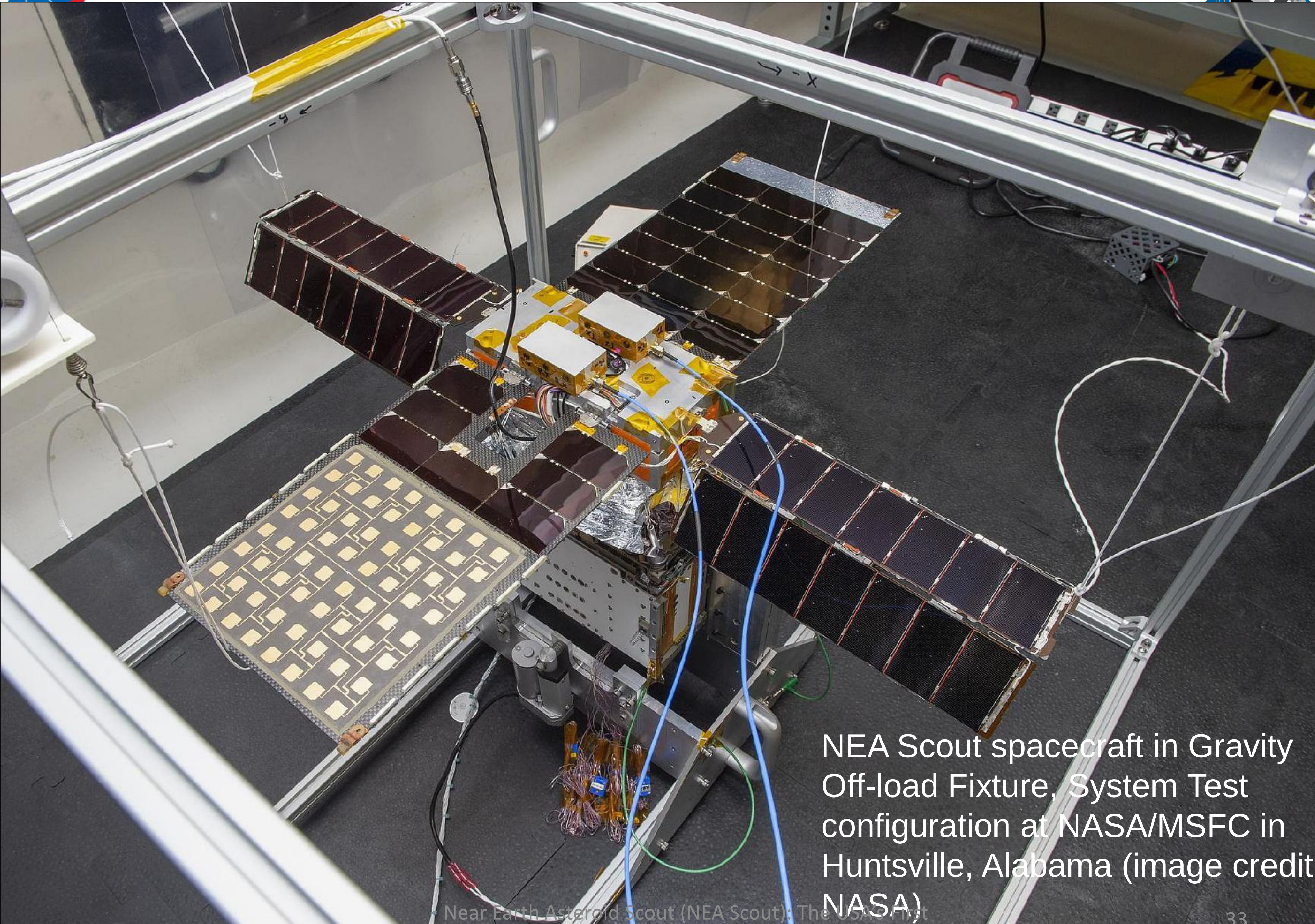

(Credit: National Geographic)



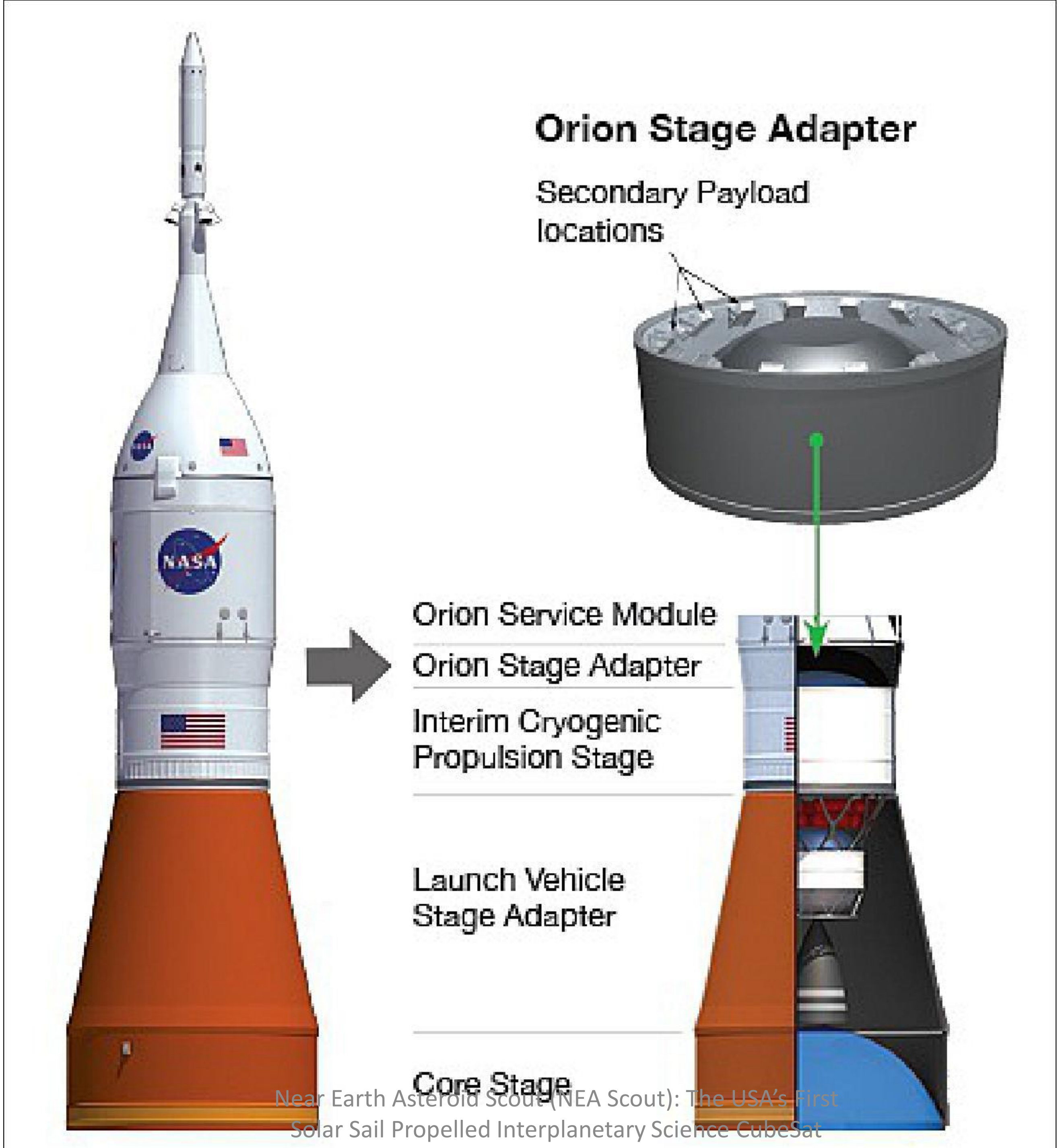
Integrated NEA Scout spacecraft on assembly fixture

The Whole NEA Scout Spacecraft is Revolutionary





NEA Scout spacecraft in Gravity Off-load Fixture, System Test configuration at NASA/MSFC in Huntsville, Alabama (image credit: NASA)


Orion Stage Adapter
Secondary Payload locations
Orion Service Module
Orion Stage Adapter
Interim Cryogenic Propulsion Stage
Launch Vehicle Stage Adapter
Core Stage

NASA's Near-Earth Asteroid Scout (NEA) ready for Artemis I Launch

July 19, 2021 |

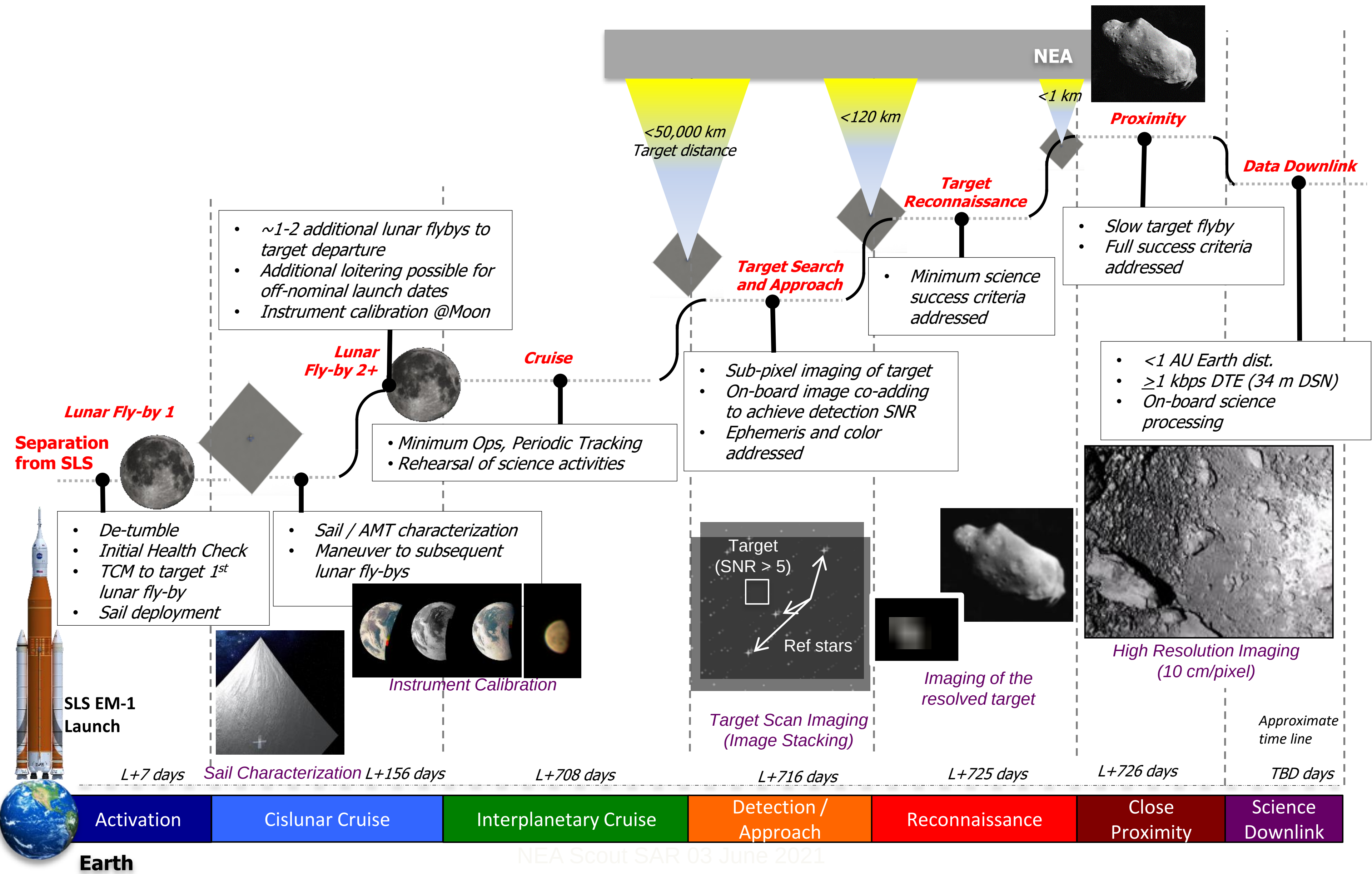
Facebook Twitter Pinterest 1

Pasadena, CA – NASA's Near-Earth Asteroid Scout (NEA) is tucked away safely inside the agency's powerful Space Launch System (SLS) rocket at NASA's Kennedy Space Center in Florida. The solar sailing CubeSat is one of several **secondary payloads** hitching a ride on **Artemis I**, the first integrated flight of the agency's SLS and the Orion spacecraft.

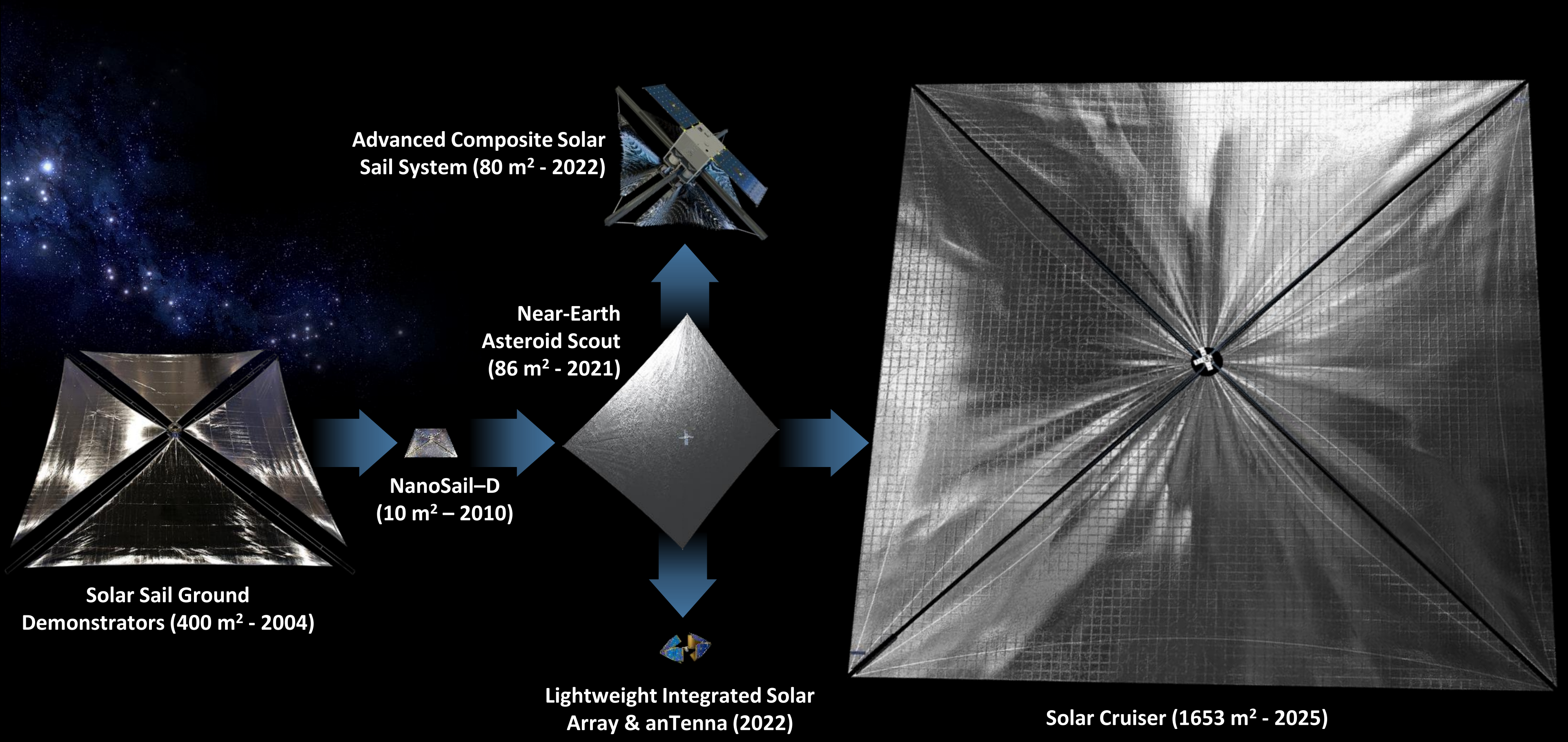
NEA Scout, a small spacecraft roughly the size of a large shoebox, has been packaged into a dispenser and attached to the adapter ring that connects the SLS rocket and Orion spacecraft.

Engineers prepare NEA Scout for integration and shipping at NASA's Marshall Space Flight Center in Huntsville, Alabama. (NASA)

Concept of Operations (ConOps) Overview



Two Decades of NASA Solar Sail Development
Increasing Solar Sail Capabilities



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